

Study the Performance of Photovoltaic Solar Panels Under Different Climatic Conditions

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ABSTRACT

The problem of energy production and its relationship with environmental pollution is one of the most important problems that many countries suffer from. With the decline in prices and the multiplicity of their applications, the use of solar panels has become widespread in many places and under various environmental conditions. The relationship between the efficiency of solar panels and their environment is one of the most important things, in order to ensure a stable and permanent supply of electrical energy, as well as to maintain the durability of these panels for a longer period. In this paper, we conducted an experimental study of the effect of some environmental factors, such as temperature, wind, snow accumulation, dust and shade, on several solar panels in order to know precisely the effect of each of them.

I. Introduction

Photovoltaic energy has great importance in the current era as one of the main sources of sustainable and clean energy, which depends on the conversion of sunlight into electrical energy using solar cells [1].

The photovoltaic effect is a kind of photoelectric effect, which is realized in photovoltaic cells and uses solar radiation to generate electricity [2]. This effect is obtained by absorbing photons in a semiconductor material. The photovoltaic panel is composed of a series of photovoltaic cells protected by glass on the front and plastic on the back [3]. The whole is vacuum encapsulated in a polymer that is as transparent as possible. The efficiency and performance of photovoltaic (PV) modules can be affected by various aggressive environmental parameters [4]. These parameters play an important role in the performance of solar systems. Understanding and mastering these parameters is essential to ensure the sustainability and reliability of solar installations and provides solutions for improving PV modules under different operating conditions [5]. This work conducted an experimental study of the effect of some environmental factors, such as temperature, wind, snow accumulation, dust and shade, on several solar panels in order to know precisely the effect of each of them.

II. The various aggressive parameters affecting the performance of photovoltaic modules in their environment

With the development of solar panel manufacturing technology and the decline in their prices in world markets, the use of solar panels has become widely used in various fields and locations. The study of the impact of environmental factors on the operation of solar panels has become necessary, as these factors lead to a decrease in the efficiency of electric power generation as well as its sustainability. The Fig (1) shows the most important environmental factors that affect the operation of solar panels directly or indirectly [5].

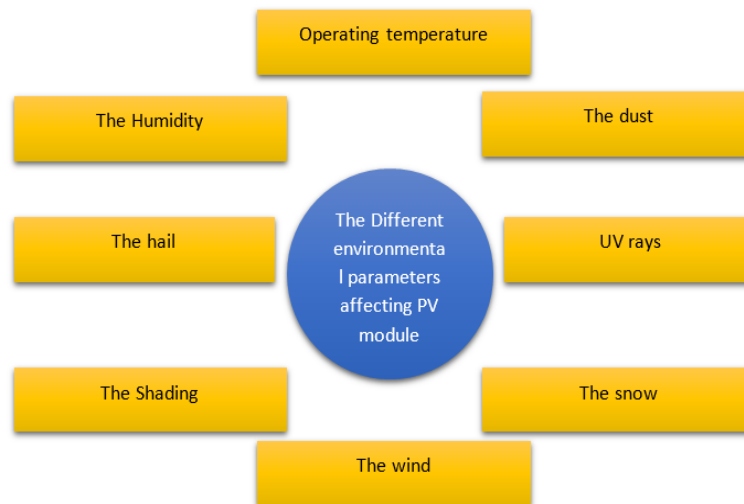


Figure 1. The most important environmental factors that affect the operation of solar panels.

III. Results and Discission

III.1. Solar irradiation effect on PV module

To study the effect of solar irradiation on the electrical performance of the PV module, we carried out the following experiment :

- The solar panel is placed facing south at a tilt angle of 36 degrees (optimal tilt angle for the city of Bou Ismail Tipaza) Fig (2).
- The reference cell (Si-V1.5TC-BATT) is displayed next to the PV module with a digital multimeter which allows the calculation of solar irradiation.
- A solar simulator type Prova 200A is used with the solar panel to trace the curve of the solar cells.

After the step of measuring the effect of variation of solar radiation on the PV module, we move on to the data acquisition on the PC. For this, we use the Solar-Module-Analyzer data acquisition software Fig(3).



Figure 2. External test bench. 1) mechanical structure with a 36° inclined plane, 2) grouping frame, 3) polycrystalline solar panel, 4) Prova200A solar simulator, 5) Multimeter (LINI-T, UT71E), 6) Reference cell (Si-V1.5TC-BATT).

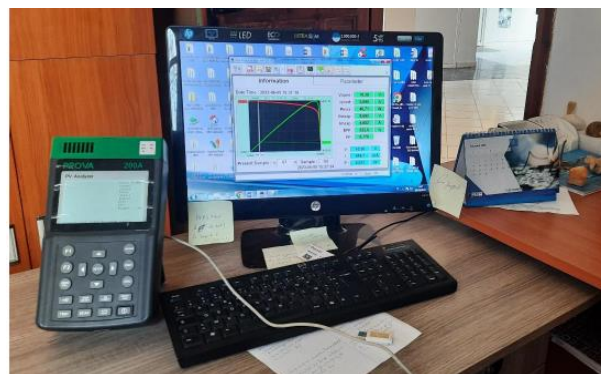


Figure 3. Data acquisition bench.

Figures (4) and (5) show the variation of I-V and P-V characteristics as a function of the variation of irradiation. It can be seen from these figures that the performance of the PV module varies proportionally with the increase in the solar irradiation value. The electrical parameter responsible for this improvement is the short-circuit current.

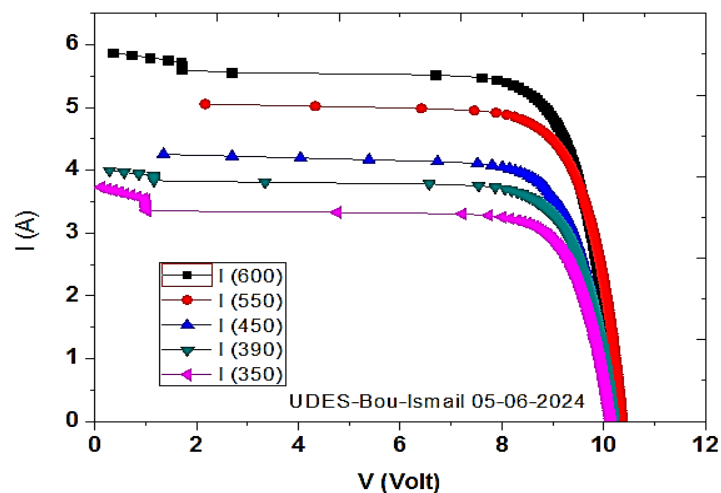


Figure 4. Effect of solar irradiation on the I-V characteristic.

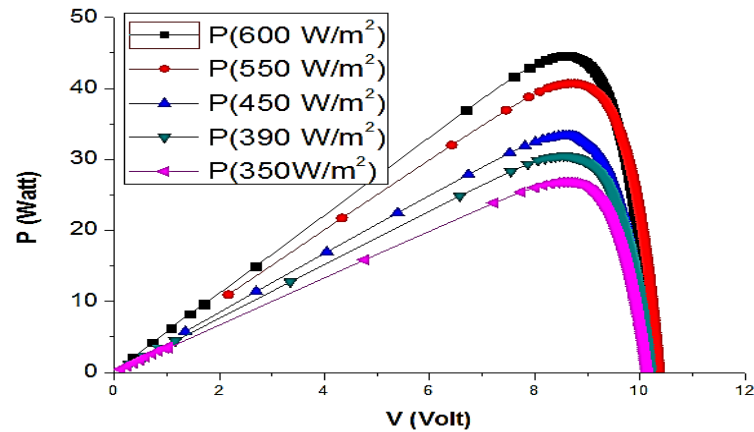


Figure 5. Effect of solar irradiation on the P-V characteristic.

III.2. Effect of temperature on PV module performances

In this part, the following external test bench is carried out, with the latest generation PV module of the JA-SOLAR type (JAM72S10-410/MR) Fig(6). The study is carried out at noon under an illumination of 870W/m² and an ambient temperature of 24°C. In order to conduct the experiment at a variable temperature and under the same solar radiation, we use water to cool the solar panel. A K-type thermocouple is glued to the backside of the PV module to measure its temperature.



Figure 6. JA-SOLAR PV module under external temperature effect test.

The test results are shown in Figures (7, 8 and 9). The PV module is tested between 30°C and 42°C. From these results, we notice a degradation on the maximum power with a drop on the open circuit voltage and a slight increase in the short circuit current.

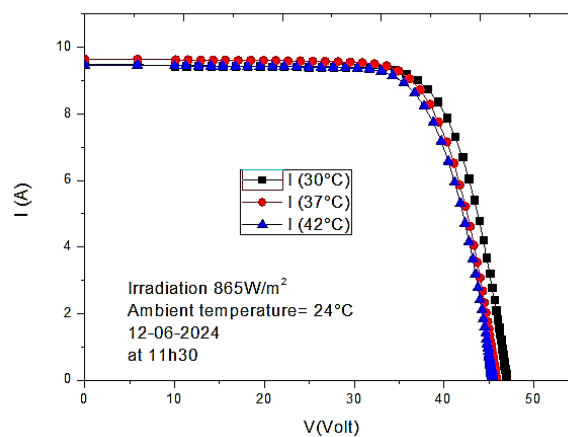


Figure 7. The effect of temperature on the I-V characteristic.

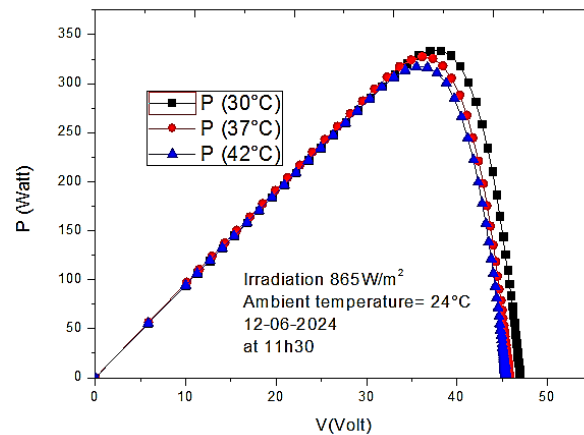


Figure 8. The effect of temperature on the P-V characteristic.

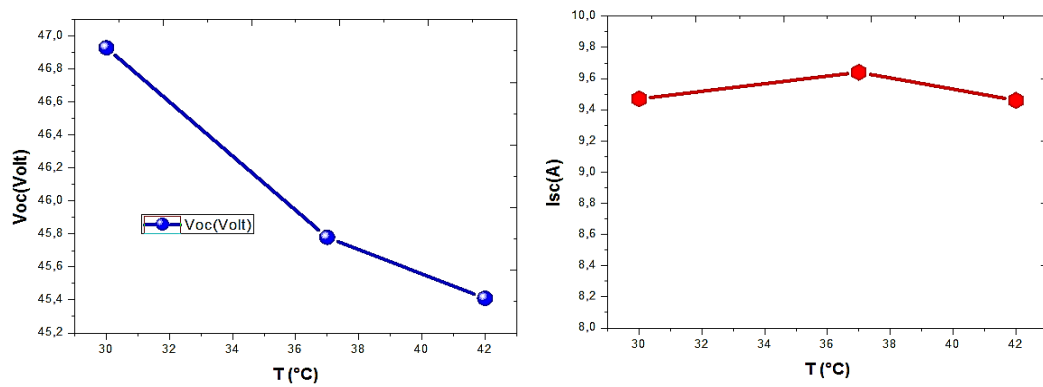


Figure 9. The effect of temperature on the open circuit voltage and short circuit current of the JA-Solar module.

III.3. Effect of partial shading on PV module performance

To study the effect of partial shading on the modules, we carried out an experimental study outdoors on a PV module of the latest generation of the JA-SOLAR 415Watt type. This PV module is of polycrystalline Si type of half-cut technology. We have a partial shading of 25% and 50% of the surface of the PV module as it is presented in figure (10).



Figure 10. Outdoor test bench the effect of partial shading on the PV module (0%, 25% and 50%).

After testing the PV module under the three shading positions under 870w/m2 outdoor illumination, the

obtained results are shown in Fig (11) and Table (1). It is noted that in the presence of partial shading the short-circuit current and the maximum power decrease by a large difference compared to the open-circuit voltage for 25% or 50% shading. Unlike the conventional PV module technology, with the JA-SOLAR PV module technology, the I-V characteristic does not have a staircase, the PV module is divided into two parts (Fig. 12), when one part is affected by the shade the second part remains functional.

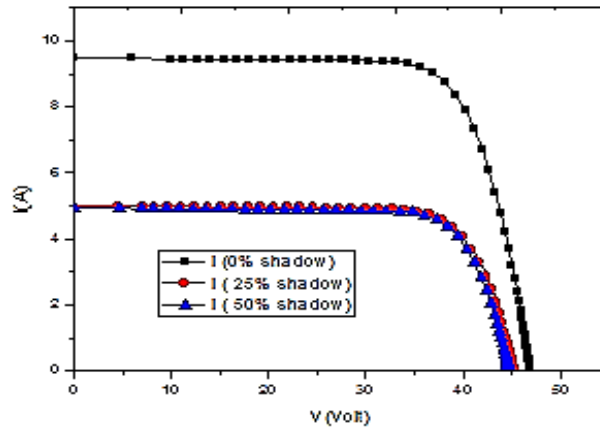


Figure 11. The effect of partial shading on JA-SOLAR module.

Table 1. JA-Solaire PV module test result.

Shading rate (%)	Voc (Volt)	Ics (A)	Pmax (Watt)
0%	46.93	9.47	334.7
25%	45.29	5.00	173.3
50%	44.69	4.93	170

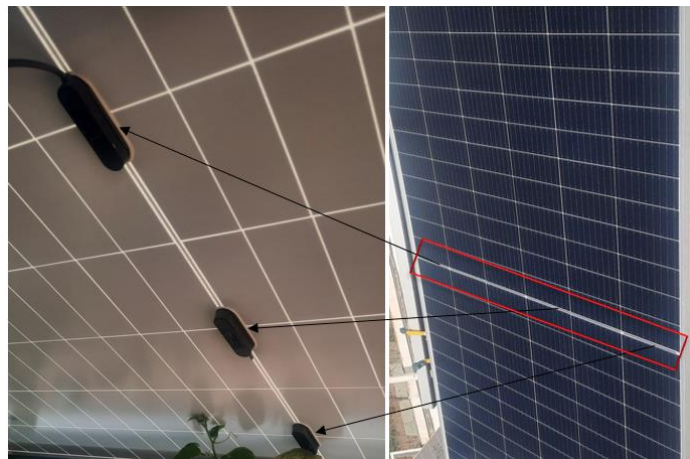


Figure 12. Rear face of JA-Solar PV module (Junction box).

III.4. Effect of wind on PV module

In order to study the effect of wind on solar panel. We installed two PV modules callivare type with 4.1Watt power with tilt angle of 36°. One of the two modules is installed facing the wind, on the other hand the second panel is hidden behind an obstacle as shown in Fig (13). The ambient temperature during the experiment is 35°C. The temperature of the PV module is 48.9°C at the beginning of the experiment. A multimeter with thermocouple was used to measure the PV modules temperature and a hot wire thermo-anemometer to measure the wind speed.

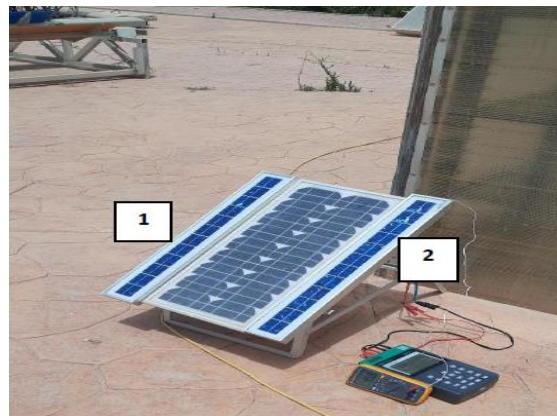


Figure 13. Outdoor wind test bench.

The results obtained are shown in Fig (14). From this figure, we notice that more the wind speed increases, the more the open circuit voltage and the maximum power increase. This is explained by the circulation of cold wind (ambient temperature 35°C) on the surface of the exposed PV module which allows to minimize its temperature (48.9°C). The effect of the wind in this case has a positive effect on the performance of the PV module.

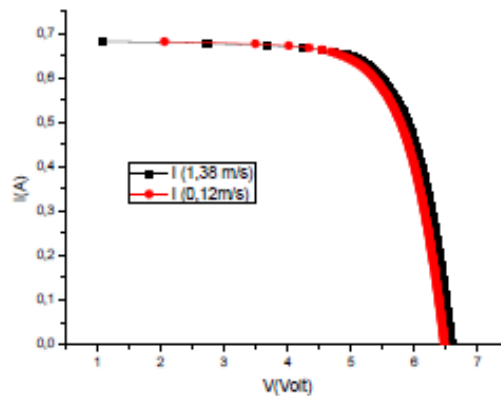


Figure 14. Effect of wind on characteristic (I-V).

III.5. Effect of snow on the module

In this part, ice pieces are used to simulate the effect of snow on the PV module. The test is carried out in external conditions, at an ambient temperature of 32°C and under a sunshine of 623W/m² on 07/20/2024 at 1:00 p.m. at UDES. To study the effect of snow on the electrical parameters of the PV module, we carried out the following experiment Fig (15):

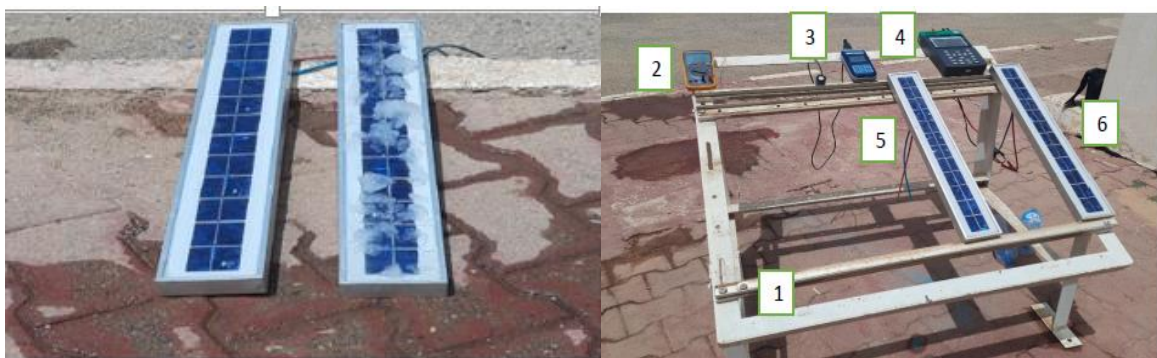


Figure 15. Outdoor test bench: 1) a 36° inclined plane, 2) a multimeter with thermocouple, 3) a photo radiometer, 4) Prova200A solar simulator, 5) uncooled solar panel, 6) cooled solar panel.

We have carried out a test after the melting of the ice, the result of which is shown in the following two figures (16 and 17). It can be seen that when the temperature decreases, the open circuit voltage increases, therefore the maximum power increases. In this case, the snow effect has a positive effect (cooling) on the performance of the PV module (the module Fig(15)).

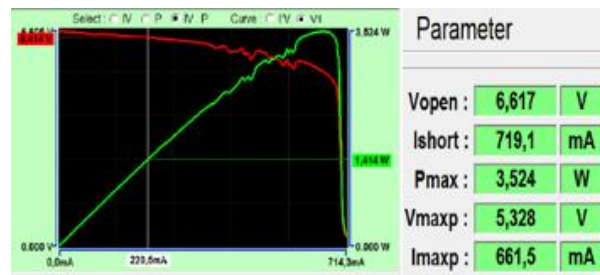


Figure 16. Characteristics I-V and P-V without ice.



Figure 17. I-V and P-V characteristics after ice melt.

III.6. Effect of dust on the electrical performance of the PV module

In order to achieve our objective, which is imposed on the study of the effect of dust on solar irradiation, we used the experimental device represented in the following figure (18). A reference cell of type (Si-V-1.5TC-batt-E) measured the irradiation value, A lamp as a source of light, A piece of square glass 10×10cm, to deposit the dust, A digital scale to measure the amount of dust deposited. The principle of reference cell measurement is based on the voltage measured by a multimeter connected with this reference cell, the reference cell is calibrated in such a way that the voltage measured by the multimeter has a direct link with the variation of solar irradiation (W/m²), according to the following quantity: 1.5 Volt represents 1000W/m².

It is noted from the results obtained illustrated in Fig .19 that the degradation of the irradiation of the light received by the Ref cell is a linear function of the deposited dust.



Figure 18. Experimental test bench.

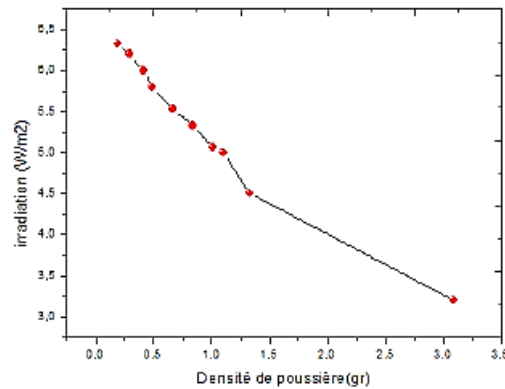


Figure 19. Variation of the irradiation captured by the Ref cell as a function of dust density.

IV. Conclusion

This study investigates the consequences of the influence of external factors on the efficiency of photovoltaic panels in terms of electrical and thermal properties. Based on the experiments presented in this paper, we conclude the following:

The efficiency of solar panels varies considerably between hot and cold environments due to the influence of temperature on the performance of photovoltaic (PV) cells.

Shading affects photovoltaic modules, whether it is total shading by reducing the amount of sunlight reaching the photovoltaic cells, or partial shading by generating hot spots.

Dust accumulation can also cause the solar modules to become hotter, which can reduce their electrical efficiency and potentially damage them, and creates hot spots when part of the solar panels are partially shaded.

Snow has a positive and negative effect on solar panels. Positive effect, cooling of the PV panels after they melt and negative effect, It acts as an obstacle that prevents sunlight from reaching the solar cells. Which reduces their efficiency.

Wind can cool PV modules (cold wind) with a positive effect, which improves their efficiency. On the other hand, wind can overheat PV modules (hot wind), which reduces their efficiency. Wind can also help to clean and damage (strong wind) PV modules.

As a future perspective for this work, we propose to realize and design photovoltaic systems more adapted to their working environment, with detection and intervention systems against the accumulation of dust and high temperature.

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